# AIR FORCE SPACE COMMAND
# ACTION OFFICER GUIDE
# FOR
# RELIABILITY AND MAINTAINABILITY

1 SEPTEMBER 1988



**AIR FORCE SPACE COMMAND**
**INTEGRATED LOGISTICS SUPPORT DIRECTORATE**
**PETERSON AFB, CO 80914-5001**

# AIR FORCE SPACE COMMAND ACTION OFFICER GUIDE TO RELIABILITY AND MAINTAINABILITY

## PREFACE

The Secretary and Chief of Staff of the Air Force stated the Air Force commitment to reliability and maintainability (R&M) in their joint memorandum of September 1984 and renewed the commitment in July 1986. An Air Force R&M 2000 Action Plan was developed to provide general policy and guidance to institutionalize R&M in the way we do business - both now and in the future.

In response, Air Force Space Command/LKYY outlined Command goals in the Reliability and Maintainability Program Plan which provides approaches to improve R&M performance and achieve AF R&M 2000 goals. This R&M Action Officer Guide is an integral part of LKYY's efforts to expand the R&M Program Plan so that AF Space Command action officers can understand R&M parameters and how they impact system capability and performance. This guide illustrates how R&M principles should be applied to new acquisition programs as well as to fielded systems.

I fully endorse this Guide and expect all AF Space Command action officers who are involved in the acquisition process to not only familiarize themselves with its contents but, more importantly, to utilize this information to ensure we get low cost, high performance space systems.

DONALD J. KUTYNA
Lieutenant General, USAF
Commander

## LIST OF FIGURES



## LIST OF APPENDICES

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AF | Air Force |
| AFLC | Air Force Logistics Command |
| AFOTEC | Air Force Operational Test & Evaluation Center |
| AFR | Air Force Regulation |
| AFSC | Air Force Systems Command |
| AFSPACECOM | Air Force Space Command |
| Ao | Operational Availability |
| BITE | Built-In Test Equipment |
| CDR | Critical Design Review |
| CDRL | Contract Data Requirement List |
| CD/V | Concept Demonstration/Validation Phase |
| CE/D | Concept Exploration/Definition |
| DT&E | Development Test & Evaluation |
| FSD | Full-Scale Development |
| ILS | Integrated Logistics Support |
| ILSMT | Integrated Logistics Support Management Team |
| ILSP | Integrated Logistics Support Plan |
| IOC | Initial Operational Capability |
| IOT&E | Initial Operational Test & Evaluation |
| JRMET | Joint Reliability & Maintainability Evaluation Team |
| JSOR | Joint Service Operational Requirement |
| LCC | Life Cycle Cost |
| LSA | Logistics Support Analysis |
| LSAR | Logistics Support Analysis Record |
| MDC | Maintenance Data Collection |
| MDT | Mean Down Time |
| MIL-STD | Military Standard |
| MNS | Mission Need Statement |
| MTBCF | Mean Time Between Critical Failures |
| MTBF | Mean Time Between Failures |
| MTTR | Mean Time to Repair |
| OS | Operations Support Phase |
| P/D | Production/Deployment Phase |
| PDR | Preliminary Design Review |
| PMD | Program Management Directive |
| PMP | Program Management Plan |
| PMR | Program Management Review |
| PMRT | Program Management Responsibility Transfer |

| | |
|---|---|
| RFP | Request for Proposal |
| R&M | Reliability and Maintainability |
| R&MAAA | R&M Allocations, Assessment and Analysis |
| RMMP | R&M Management Plan |
| R(t) | Reliability function at Time (t) |
| SAF | Secretary of the Air Force |
| SDR | System Design Review |
| SON | Statement of Operational Need |
| SORD | System Operational Requirements Document |
| SOW | Statement of Work |
| SPO | System Program Office |
| SPR | Secretary's Program Review |
| SRR | System Requirements Review |
| TEMP | Test & Evaluation Master Plan |
| USAF | United States Air Force |
| WMP-3 | War Mobilization Plan-3 |

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

Although R&M had long been recognized as important considerations in fielding major weapon systems, the emphasis on R&M in an acquisition program usually took a back seat to cost, schedule and performance, especially when trade-offs were required to offset budgetary constraints. These cost cutting practices reduced up front development/procurement costs but resulted in increased long term operations and support costs. To combat the mounting cost of supporting our space and ground systems, the Secretary and Chief of Staff of the Air Force have promulgated vigorous Air Force commitment to R&M:

> "For too long, the reliability and maintainability of our weapon systems have been secondary considerations in the acquisition process. It is time to change this practice and make R&M primary considerations."
>
> "We must emphasize R&M throughout the acquisition process--from requirements definition, throughout concept development, design, production and acceptance. Everyone must ensure R&M requirements are met through every step of the process. **R&M must be coequal with cost, schedule and performance** as we bring a system into the Air Force inventory."
>
> (General Charles Gabriel, Chief of Staff, USAF, and Mr. Verne Orr, SAF, 17 Sep 1984)

## 1.2 PURPOSE OF GUIDE

This guide is designed to help action officers responsible for managing acquisition programs better understand the interrelationship between R&M performance and operational capability. It won't turn you into an R&M engineer.

This guide is designed to be used with the Command Management Guide developed by XPT and the Reliability and Maintainability Terms for Space, Space Surveillance, and Missile Warning Systems technical report published by LKY.

The XPT guide is a comprehensive document that provides a single source of reference for the staff officer. It contains an overview of the acquisition process and outlines the command manager's responsibilities. For more information, contact HQ AFSPACECOM/XPT, Peterson AFB, CO 80914-5001 or call AV 692-5668.

The LKY technical report details both mission and logistics support R&M parameters. The terms and definitions contained in the report are approved for use in SONs and SORDs. To obtain a copy of this report, contact HQ AFSPACECOM/LKYY, Peterson AFB, CO 80914-5001 or call AV 692-3286/5898.

## 1.3 OVERVIEW

The basic guide discusses the role of R&M in requirements determination and system acquisition process. Appendix A is a primer of basic R&M concepts and computations. Appendix B is a checklist designed to evaluate R&M content in System Operational Requirements Documents (SORDs). Contract data items applicable to R&M are listed in Appendix C.

# 2.0 R&M IN THE SYSTEM'S LIFE CYCLE

## 2.1 OVERVIEW OF PHASES

System acquisition programs normally go through several phases, each with particular milestones, as they progress from the identification of a need to final operational deployment. Figure 2-1 shows the acquisition process and the major events/documents that usually occur in each phase. Phases may be combined or omitted depending on circumstances; however, each phase is designed to develop a level of confidence in the solutions offered and to reduce the risks of entering the next phase. R&M is a key factor in the decision process as the program progresses through each phase.

## 2.2 MISSION AREA ANALYSIS PHASE

The acquisition process begins with a mission area analysis identifying mission requirements and assessing the Command's capability to fulfill each requirement. Statements of Operational Need (SONs) define new requirements that cannot be met through changes in tactics, strategy, doctrine, or training. The SON also offers a possible solution involving either new equipment or upgrades to an existing system. Section 3 describes placing R&M requirements on SONs. Once the SON is validated by the Air Staff, it forms the basis for writing the Program Management Directive (PMD). The System Program Office (SPO) selected for the project then develops a Program Management Plan (PMP) that describes the tasks necessary to develop a system that fulfills PMD requirements. The operational command is also tasked to develop a System Operations Requirements Document (SORD) which amplifies and refines the operational and support needs specified in the SON. R&M considerations for these documents are discussed in Section 3.

## 2.3 CONCEPT EXPLORATION/DEFINITION (CE/D) PHASE

In the CE/D phase, the implementing command (normally AFSC for a major new weapon system) may have several companies in competition for the award winning design. Operations and support planning are integral activities during this phase. Contractual R&M requirements are developed to the same extent as are other performance parameters. As system operating and support concepts are further developed during the acquisition process, operational R&M needs and the corresponding contractual R&M requirements are challenged and refined. The objective of this refinement process is to have R&M needs and contractual requirements that are validated, consistent, achievable and acceptable by the operating, implementing, and supporting commands prior to

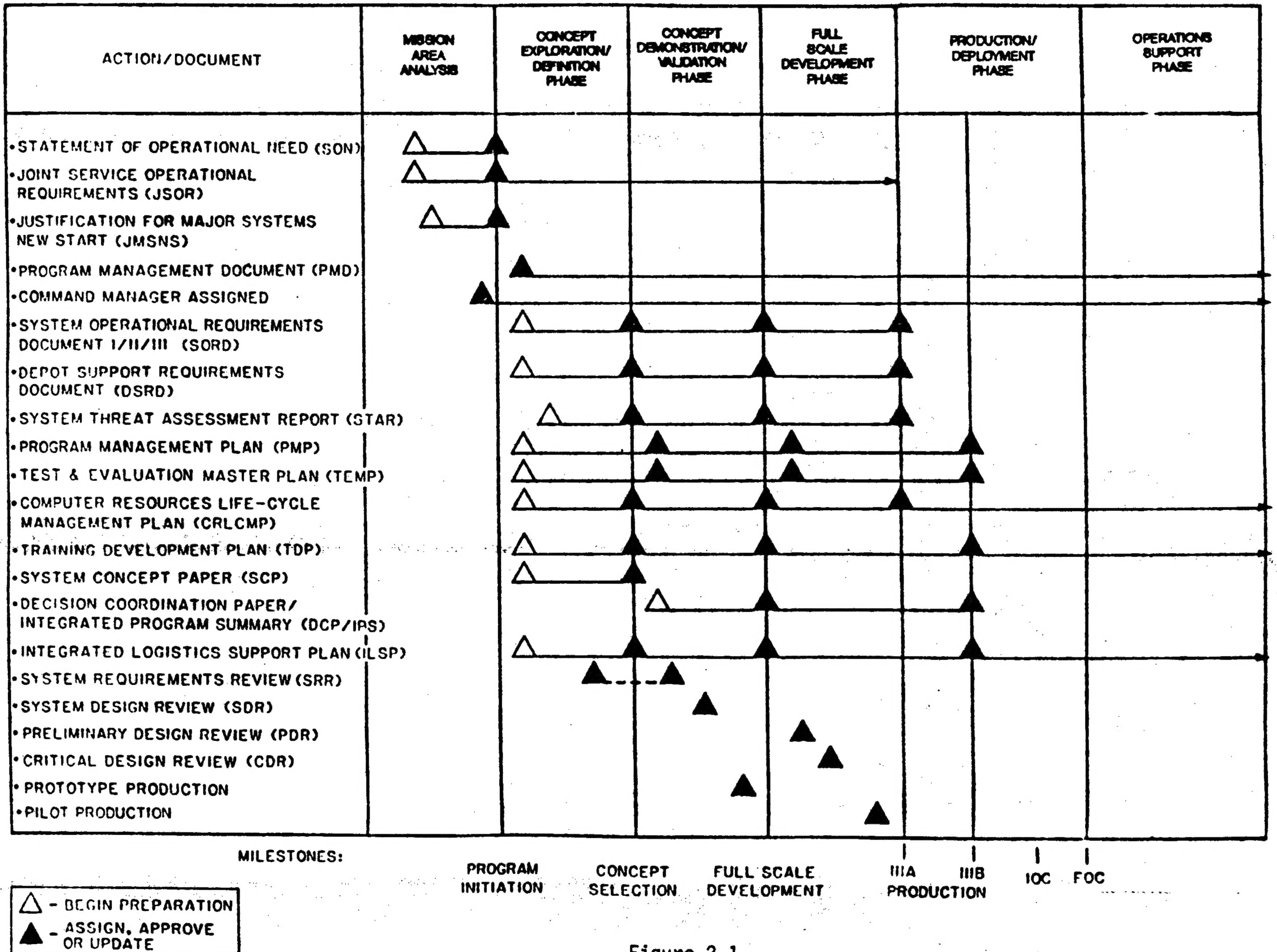



Figure 2-1

**ACQUISITION PROCESS WITH KEY EVENTS**

developing the Full Scale Development Request for Proposal (FSD RFP). Section 5 explains R&M tasks in the contractual process.

By the end of the CE/D phase, decisions affecting 70% of the Life Cycle Costs (LCC) have already been made, and decisions affecting 85% of the LCC are made prior to Full Scale Development (FSD), as shown in Figure 2-2. These decisions affect system supportability, R&M characteristics, and LCC. For maximum benefit, R&M requirements must be clearly stated in early acquisition documents including the System Operational Requirements Document (SORD), the R&M Management Plan (RMMP), and the Test and Evaluation Master Plan (TEMP). These documents are discussed in Sections 3 and 6.

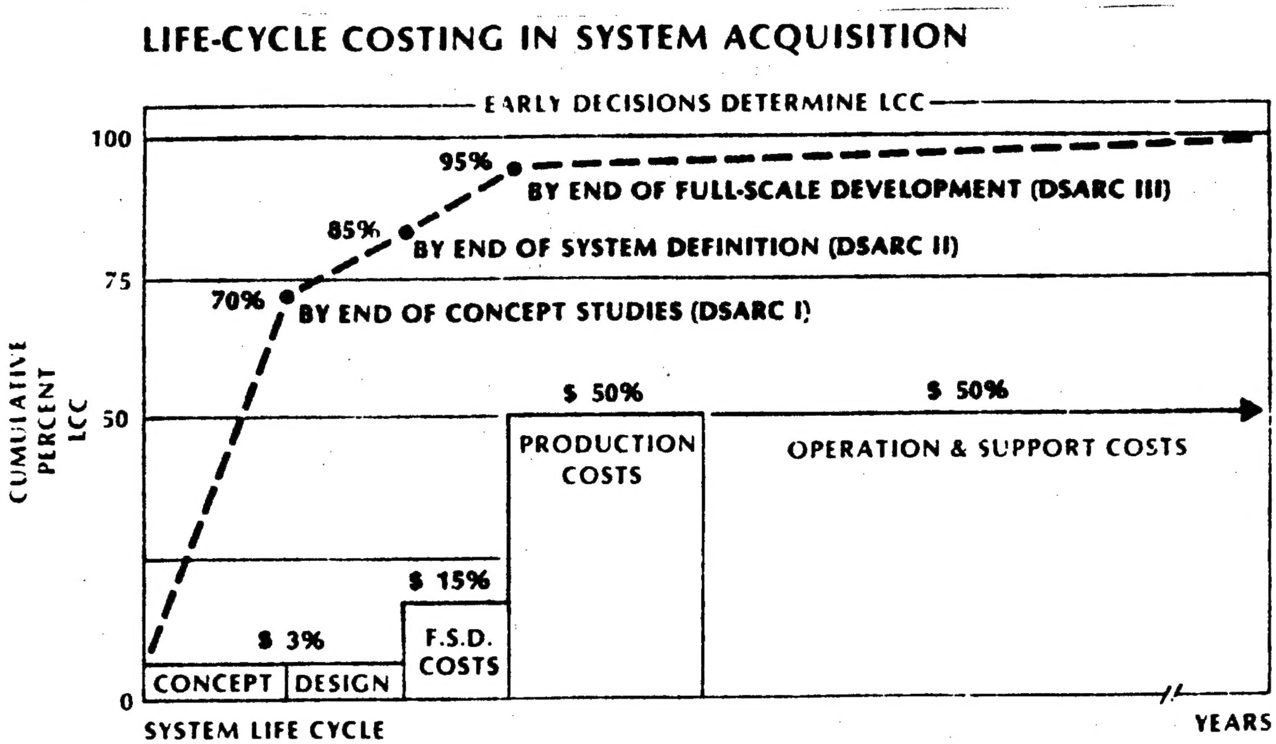



Figure 2-2

## 2.4 CONCEPT DEMONSTRATION/VALIDATION (CD/V) PHASE

When the exploration of alternative system concepts has been completed to the point where the selected alternative warrants system demonstration, the program enters the CD/V Phase. The purpose of this phase is to reduce technical risk and economic uncertainty through a more detailed definition of the system. The System Program Office (SPO) works closely with the contractor(s) to further define the system and will frequently task them to build prototypes and/or accomplish desktop analysis to provide necessary detail. These details are included as updates to the documents first published in the Concept

Exploration/Definition phase. Therefore, much of the R&M work in this phase of the acquisition is a continuance of work done previously. R&M requirements are allocated down to the subsystems and/or equipment items within the system. Certain meetings (i.e., System Requirements Review (SRR) and System Design Review (SDR)) are held to review the system requirements and detailed design. R&M requirements for these reviews are described in Section 5.

## 2.5 FULL SCALE DEVELOPMENT (FSD) PHASE

Upon final selection of a design concept, the system is ready to enter the FSD Phase. The implementing command will reaffirm the operational need for the system, adequacy of evaluation of the alternative approaches, adequacy of the test and evaluation approach, sufficiency of cost and schedule estimates, and consistency of the acquisition strategy and contractual plan with program characteristics, requirements and risk. Once this review, called the Secretary's Program Review (SPR) is completed, the implementing command will enter FSD. Contract requirements for R&M are the same as those in the earlier phases (see Section 4). Once the contract is awarded, two major reviews, the Preliminary Design Review (PDR) and Critical Design Review (CDR), are conducted to check the contractor's progress and ensure the technical adequacy of the design approach. During this phase, the action officer must review the test planning documentation to evaluate the DT&E and IOT&E efforts against the operational requirements. Once the test has been conducted, there are reviews of the test results to determine how well the actual system meets operational and support requirements. R&M is a determining factor in how well the system passed OT&E, as described in Section 7. Finally, there is another SPR at the end of FSD to make the final decision to accept the prototype as a one of a kind or to mass produce the system. R&M issues for this SPR are identical to those of the previous SPR, described in Section 6.

## 2.6 PRODUCTION/DEPLOYMENT (P/D) PHASE

Once the system design has been fully developed, approval can be given to enter the P/D phase. For a major program involving large production quantities, producibility and reliability growth are examined. Large production runs don't normally occur for the typical Space Command acquisition; the prototype system frequently becomes the operational system. Sometimes an evolutionary acquisition strategy is used. Under this strategy, system capabilities are acquired in blocks. Each block is sequentially acquired and employed and becomes the base for the next block. This strategy is used primarily on systems which push the state of the art or on which future requirements cannot be accurately forecast. Tracking R&M requirements across

each evolutionary acquisition block is critical to achieving operational capability.

## 2.7 OPERATIONS SUPPORT (OS) PHASE

The OS phase begins with the first operational deployment. The system's operational performance is tracked and problems identified. R&M parameters affecting mission performance or supportability are closely monitored. Equipment replacement or modification may be required to maintain system level R&M performance. The importance of maintenance data collection during this phase is addressed in section 9.

2.7.1 Initial Operational Capability (IOC). At the beginning of IOC, the using command,(in this case AFSPACECOM), takes operational responsibility IAW AFR 800-19. Normally some time later, management responsibility for the system transfers to AFLC as part of Program Management Responsibility Transfer (PMRT), IAW AFR 800-4. R&M tasks in this phase are normally limited to Follow on OT&E (FOT&E) (described in Section 8), and the establishment of a Maintenance Data Collection (MDC) System to track actual R&M performance.

2.7.2 Full Operational Capability (FOC). Once the system is fielded, efforts are made to improve system effectiveness and safety. The acquiring agency continues to correct operational R&M deficiencies caused by material, software, or firmware design and quality. The program manager corrects operational R&M deficiencies within his/her responsibility and assures that operational R&M needs are met. The operating and support commands correct deficiencies that are the result of inadequate operating and support concepts. After PMRT, the operational R&M performance is monitored and reported through a MDC system. Analysis is performed to assess operational R&M performance, identify deficiencies, and help identify corrective actions. This becomes the basis for a new SON, thus reinitiating the process.

## 3.0 R&M IN PROGRAM DOCUMENTS

The Statement of Need (SON) documents the operational command's requirements. Once the SON has been validated and funding acquired for the program, the program enters the concept exploration phase. At this point in the acquisition, three documents are important: the PMD, PMP and SORD.

### 3.1 STATEMENT OF OPERATIONAL NEED (SON)

A SON defines an operational need and documents official validation of the need. A SON is an AF-related document. Other documents that describe a need are the Joint Statement of Requirements (JSOR), Mission Need Statement, Required Operational Capability (ROC) or Communications-Computer System Requirements Document (CSRD). While the documents differ in form and content, putting R&M requirements into each of them follows a similar logic flow.

3.1.1 Defining Requirements. The first step in adequately preparing a SON with the proper R&M terms is to understand that SONs document the need for a new or improved capability, identify operational deficiencies, and define constraints on acceptable solutions. During the SON development, R&M parameters are defined at the system level. Stating top level R&M needs early in the acquisition cycle helps determine the best design solution by ensuring R&M considerations are an inherent part of the system design process.

Inherent in the mission need are certain top level readiness requirements. These readiness requirements should relate to the peacetime and wartime scenarios envisioned. For example, if you are writing a SON for a ground communications system, general wartime requirements from the War and Mobilization Plan-3 (WMP-3) might specify the equipment be operated 24 hours a day/7 days a week. If the equipment is on a transportable platform, it may be required to operate without resupply for a specified minimum period of time.

3.1.2 Requirements Allocations. Once top-level operational requirements are established, the R&M values should flow down from and support these requirements. Most Space Command systems are low-density (normally one per geographic location and less than 20 locations worldwide) or one-of-a-kind space and attack warning systems. These systems often have to meet extremely high R&M effectiveness criteria. To develop or evaluate R&M requirements, the operational need must be completely understood. Factors including the system's mission, its operations concept and maintenance concept must be considered.

As a minimum, the following R&M parameters must be determined and included in Section IV A of the SON:

-- Mission Reliability
-- Mean Mission Duration
-- Mean or Maximum Restoral Time
-- Availability/Dependability

For further information on the use/application of these terms, consult AFSPACECOM/LKY Technical Report 88-1, Standard R&M Terms for Space, Space Surveillance, and Missile Warning Systems, dated 20 April 1988.

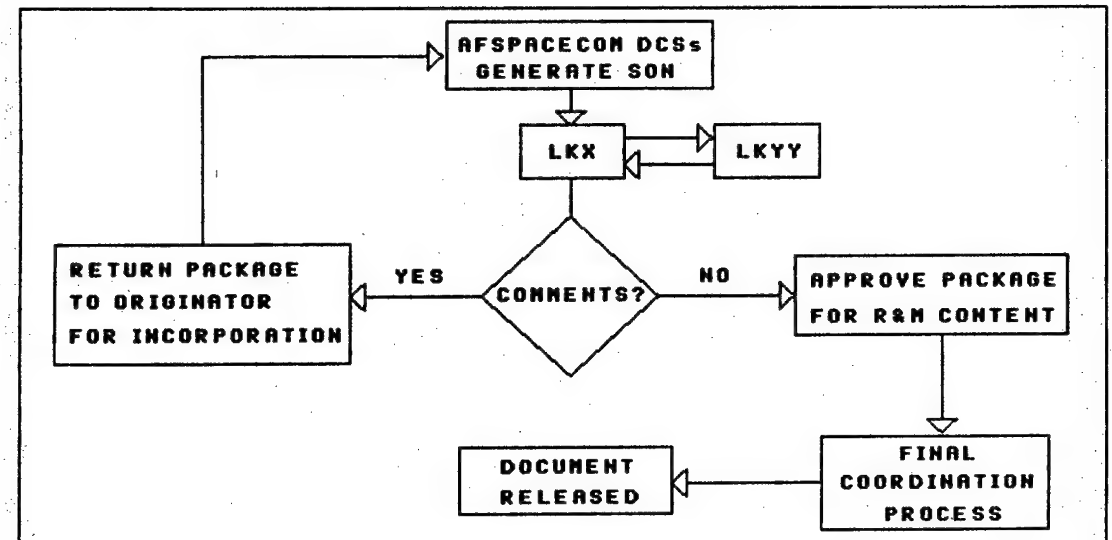
3.1.3 Quantifying Requirements Once the appropriate terms have been selected, the next decision is how much R&M to ask for. This decision should be based on mission requirements, technology, and comparable current systems. This task can be difficult due to system complexity and incomplete historical data on predecessor system outages. Also, it's not always possible to find a "like system" to use as a basis for comparison. Many of our new systems provide capabilities not previously available.

All possible sources of information should be tapped. Dialogue with contractors and engineers at Space Division and Electronic Systems Division, as well as the AF Acquisition Logistics Center (AFALC) and the AF Coordinating Office on Logistics Research (AFCOLR) can provide valuable information. Additionally, AFSPACECOM/LKYY personnel will assist you in this effort.

In AF Space Command, all SONs must process through LKYY to ensure adequate R&M parameters are inserted in the document. Figure 3-1 shows the AFSPACECOM SON validation process which ensures R&M is adequately addressed.

## 3.2 PROGRAM MANAGEMENT DIRECTIVE (PMD)

The PMD is the master program document for any 800-series acquisition. It defines the responsibilities and funding profile for the program and is the key decision-making tool to coordinate the efforts of the using/developing/supporting commands. As far as R&M are concerned, the PMD should contain a section under "Implementing Command Responsibilities" that shows what tasks are going to be performed as part of the program. Those tasks include conducting an R&M program per AFR 800-18, publishing an R&M Management Plan (see Section 7.4 for details) and integrating R&M into the logistics program. R&M tasks must be inserted in the first version of the PMD. Planning up front for an R&M program is significantly easier than trying to acquire it later because the common "bring money" arguments with the SPO can occur if the requirement for a sound R&M program is not specified up front in the PMD.




AFSPACECOM SON VALIDATION PROCESS

Figure 3-1

## 3.3 PROGRAM MANAGEMENT PLAN (PMP)

The PMP is the SPO's response to the PMD. Instructions on how to prepare it are contained in AFR 800-2. All tasks required by the PMD should show up consistently in the PMP. R&M should, as a minimum, be included in section 4 (System Engineering and Configuration Management), section 5 (Test and Evaluation), and section 9 (Logistics). If the PMD has clearly defined the R&M program's requirements, then the SPO should show how it will complete all required actions. Inadequate discussion of the R&M program in the PMP is one of the first indications of future trouble in getting the SPO to sign up to R&M.

## 3.4 SYSTEM OPERATIONAL REQUIREMENTS DOCUMENT (SORD)

A SORD is submitted by the operating command for each funded program as tasked in the PMD. The SORD is the requirements and planning document prepared to address operational and support needs. It amplifies and refines the SON. AFR 57-1 specifies the SORD format and directs that the SORD will quantify the following R&M parameters:

A) mission reliability and maintainability
B) logistics reliability and maintainability

C) operational availability and dependability

These values are described in Section IV.A.1 of the SORD. Section IV.A.1.a specifies the required system performance parameters such as capacity, mission duration, reaction time, etc. Section IV.A.1.b provides the mission reliability and maintainability parameters that the system must exhibit (see the R&M Primer and AFSPACECOM Technical Report for Standard R&M Terminology for further details). Section IV.A.1.c covers the logistics R&M (expressed as Mean Time Between Maintenance (MTBM) and Mean Time to Repair (MTTR)) for the system. Finally, Section IV.A.1.d describes the readiness measures in terms of Ao or operational dependability (Do). These four sets of parameters should be interrelated; i.e., the operational parameters should form the basis for the R&M parameters that follow. AFSPACECOM SORDs must be coordinated with LKYY who uses the SORD checklist in Appendix B to assess whether R&M issues have been adequately addressed.

## 4.0 R&M IN THE CONTRACTUAL PROCESS

The SON and SORD formalize Space Command's operational requirements. In these documents, needed capabilities are described in terms of mission requirements, operational objectives, employment, and support and maintenance concepts. The SPO then takes the operational R&M parameters stated in the SON and SORD and translates them into contractual terms such as Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), etc., to meet the SON/SORD requirements. Next, the SPO solicits private industry and public agencies for proposed solutions to this need in the Request for Proposal (RFP). The RFP includes a model contract with a SOW, System Specifications, and Contractor Data Requirement List (CDRL). The AFSPACECOM action officer must ensure that contractual terms in the specification and R&M tasks outlined in the SOW will meet SON requirements. The R&M parameters established in the SON/SORD and translated into contractual terms by the SPO hold the contractor liable.

### 4.1 SPECIFICATIONS

R&M values are normally contained in Sections 3.2.3 through 3.2.5 of the specification. Section 3.2.3 should have reliability, which will give the required MTBF or R(t) and mission duration. Both MTBF and R(t) should be specified. Section 3.2.4 gives the maintainability specifications, usually in terms of MTTR. Sometimes the SPO uses the phrase: "consistent with the reliability and availability values," but it is better to specify the requirement. As shown in the R&M Primer (Appendix A), MTTR is a contractual term that does not include logistics or administrative delay times. Therefore, the MTTR value must be less than the operational value given in the SORD. Section 3.2.5 lists the availability requirement which should be consistent with the R&M specifications above. The availability formula given in LKY/TR88-1 should balance when combining the RM&A values in these three sections.

### 4.2 STATEMENTS OF WORK (SOWs)

A SOW is the part of a contract detailing tasks the contractor must perform. R&M tasks in the normal acquisition contract include conducting an R&M program IAW MIL-STDs 471 and 781. References are also included for the development of various R&M related data. The details of the data requirements are included on the Contract Data Requirements List (CDRL).

### 4.3 CONTRACT DATA REQUIREMENTS LIST (CDRL)

The CDRL contains the requirements for data to be delivered to the government under the terms of the contract. The CDRL

contains or references the required format, delivery instructions, number and types of copies required, approval codes, frequency of updates and required delivery dates. The CDRL references a Data Item Description (DID) which describes a standard format for commonly requested data. These DIDs can be tailored to meet program specific requirements on the CDRL. Appendix C contains commonly used R&M DIDs. AFSPACECOM/LKYY will assist the action officer in selecting and tailoring these DIDs and in preparing the required CDRL information.

## 4.4 SOURCE SELECTION EVALUATION

Source selection is the process of choosing the contractor(s) who will design or build the system. Evaluation of the contractor's approach to R&M is a critical activity during source selection. The contractor must show his or her understanding of the R&M tasks, ability to perform those tasks, and a sound plan to integrate the R&M tasks into the entire system engineering and logistics support effort. Ideally, a logistician who can analyze both the logistics and R&M parts of the contractor's proposals will be a member of the Source Selection Team.

## 5.0 R&M IN DESIGN REVIEWS

### 5.1 SYSTEM REQUIREMENTS REVIEW (SRR)

The SRR is conducted to evaluate the contractor's responsiveness to the SOW and to ensure the contractor's interpretation of the system requirements is correct. At this time, it is the Action Officer's responsibility to ensure the R&M values originally placed in the SON/SORD were accurately translated by the contractor into the Proposal and that all elements of the R&M program are in place. This task should entail matching the Proposal to the SOW.

### 5.2 SYSTEM DESIGN REVIEW (SDR)

At the SDR, the contractor's proposed approach to meeting system operational requirements is reviewed. Normally this approach is documented in a draft "A" level specification. The R&M emphasis at SDR is the proper and consistent establishment of system level R&M design requirements. The R&M requirements documented in the "A" level specifications are the inherent capabilities the system must possess, given a stated system operations and maintenance concept. "A" level specification requirements are derived from the SON/SORD requirements by taking into account the impact of factors external to the system hardware and software. Often the inherent design requirements (i.e., "A" specifications) are higher than the SON/SORD requirements. The combined effects of inherent and external R&M factors are evaluated at SDR to determine if the contractor's proposed design is capable of meeting operational requirements.

### 5.3 PRELIMINARY DESIGN REVIEW (PDR)

The PDR is an important check on the contractor's progress and consistency and the technical adequacy of the design and test approach. It is held during FSD to evaluate the contractor's preliminary design effort. The contractor's functional allocation of system level requirements to individual configuration items of hardware and software is assessed to determine existing and potential problems related to system capability, equipment engineering and manufacture, and logistics supportability. The R&M emphasis at PDR is review of the contractor's proposed R&M allocations and predictions. Upon authentication of the "B" level specification following PDR, these allocated R&M requirements become design requirements and are included in the system's allocated baseline.

## 5.4 CRITICAL DESIGN REVIEW (CDR)

The next major system design milestone after the PDR is the CDR. Once the contractor has successfully completed the PDR, the detailed design effort begins. Hardware and software are chosen or designed to meet the allocated functions. At CDR the contractor's detailed design effort is evaluated against both system and functional specifications. The SPO acts as the single interface between other government offices and the contractor.

The CDR is held to evaluate the final detailed design prior to production. It will verify the functionality, producibility, and supportability of the basic design and attempt to catch oversights prior to the start of production. Heavy investments are under way at this point, so the design must be frozen and all items given to final reevaluation in order to minimize risk. The R&M emphasis at CDR is the allocation of configuration item level R&M requirements down to individual hardware and software components. Assessment of maintainability parameters against the maintenance concept and support constraints is also accomplished. Upon authentication of the "C" level specifications, the system's product baseline is established.

## 6.0 R&M IN THE DEVELOPMENT PROCESS

### 6.1 PROGRAM MANAGEMENT REVIEWS (PMRs)

PMRs are held periodically on some programs to allow the using, developing and supporting commands to review the progress of the system acquisition effort, define problems and look for solutions. The status of the logistics section of the program (including the R&M program) should be reviewed.

### 6.2 SECRETARY'S PROGRAM REVIEWS (SPRs)

For designated programs, the SPO is regularly required to report the status of the program to the Secretary of the Air Force and the Air Staff. Included is a section on the status of the R&M Program. Figures 6-1 and 6-2 give examples of the slide format used in the SPR. This material should be reviewed and coordinated through HQ AFSPACECOM/LKYY before going to the Air Staff.

### 6.3 LOGISTICS SUPPORT ANALYSIS (LSA)

LSA is a subset of the system engineering process in which support factors influencing system design and support requirements are determined. R&M parameters play a major role in LSA and are tailored for each program. LSA tasks are contained in MIL-STD-1388-1A; MIL-STD-1388-2A describes a standard LSA Record (LSAR) system. LSAR data sheets contain key R&M parameters at the system as well as the component level. System level R&M requirements are documented on the "A" sheet while the B and B1 sheets contain key component level R&M data elements.

The LSAR is designed to serve as the single point data base for logistics related design information. Reliability predictions; failure modes, effects, and criticality analyses; and maintenance manpower and equipment requirement determinations are made from and documented in the LSAR. Using the LSAR as the single point data base insures that analyses based on R&M parameters (e.g., Life Cycle Costing (LCC), Repair Level Analysis (RLA), reliability predictions, spares computations, and tasks analyses) utilize the same values.

The A sheet is completed during the CE/D phase as a result of LSA subtask 205.2.3 (specification requirements) of MIL-STD-1388-1A. It must be available prior to, or concurrent with initiation of LSA subtask 301 (functional requirements) in the CD/V phase. The action officer should obtain a copy of the A sheet and ensure that the logistics parameters listed will satisfy the SON R&M requirements.

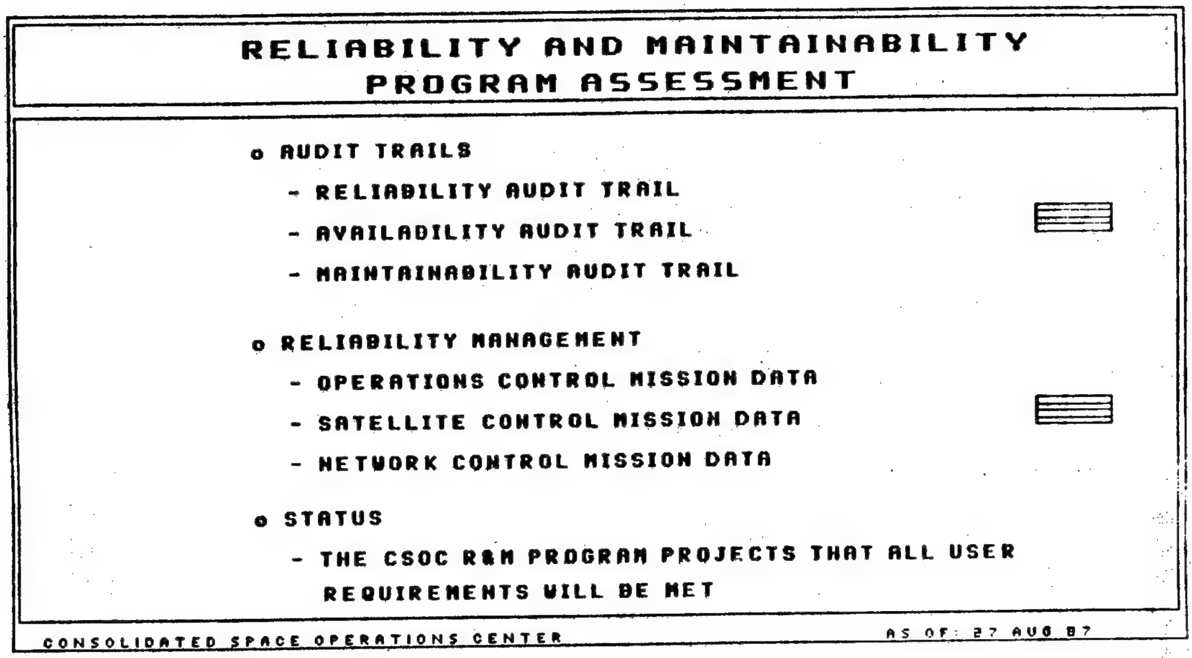



Figure 6-1

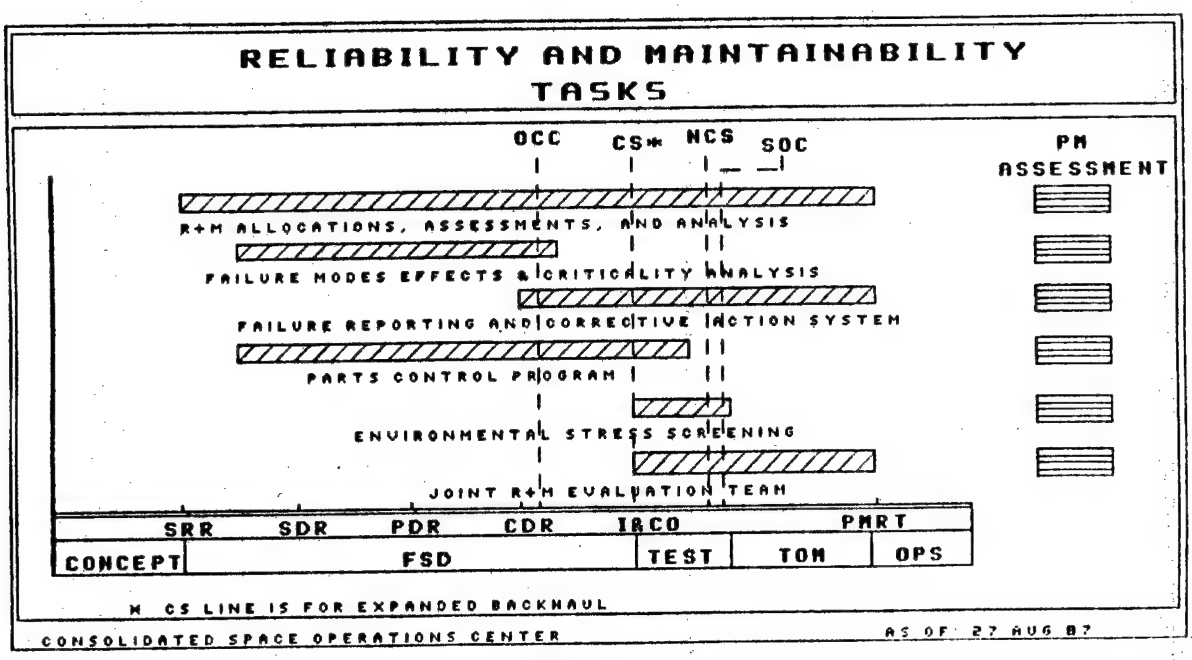



Figure 6-2

Since R&M and the ILS elements establish the criteria for the entire LSA process, it is important that the A sheet gets completed early on to allow the up-front logistics decisions necessary to field a reliable and maintainable system. The SPO will include information on the application of the LSA process in the Integrated Logistics Support Plan (ILSP).

## 6.4 SYSTEM PROGRAM OFFICE R&M DOCUMENTATION

The SPO is responsible for writing two important documents related to R&M during system development: the R&M Management Plan (RMMP) and the ILSP.

6.4.1. R&M Management Plan (RMMP). The RMMP explains the program management approach/objectives and describes its R&M program for the acquisition. The RMMP must relate to HQ USAF and AFSPACECOM R&M plans/goals and form the basis for R&M program reviews. The action officer should:

(a) review the RMMP to verify that R&M has been integrated into the entire acquisition/support process.

(b) follow up to ensure the plan is being actively executed.

Additionally, maintainability demonstrations (M demos) or assessments are conducted to evaluate the testability, access, and types of tools needed for maintenance.

6.4.2. Integrated Logistics Support Plan (ILSP). The ILSP is the key document for the overall logistics support of the new system. The ILSP is an expansion of section 9 of the Program Management Plan discussed in para 3.3. It's prepared IAW AFR 800-8, "Integrated Logistics Support Program." The ILSP covers logistics activities throughout the system's life cycle by developing an integrated series of individual plans covering the different elements of logistics support. One of these elements, Design Interface, includes the R&M program. The ILSP should adequately document the status of the R&M program and show how R&M are being used/integrated into the total ILS effort.

## 6.5 INTEGRATED LOGISTICS SUPPORT MANAGEMENT TEAM MEETINGS

Integrated Logistics Support Management Team (ILSMT) Meetings are conducted quarterly. Normally, the ILSMT Meeting is chaired by the Deputy Program Manager for Logistics (DPML) and is normally attended by representatives from the implementing, supporting, using, and test commands. AFSPACECOM/LKY provides

support to the command managers at this meeting. R&M factors have a significant impact on system supportability so R&M progress should be monitored, problems discussed and cooperative action initiated at the ILSMT meetings.

## 6.6 PREPARATION FOR TESTING

Testing is a critical function for a system acquisition. In testing we evaluate a system throughout its acquisition cycle to insure the final product will meet system requirements. Preparing for this testing begins with the establishment of a Test and Evaluation Master Plan (TEMP). The test methods used to verify the performance parameters in Section 3 of the system specification are documented in Section 4 of the same specification. The action officer should ensure the test methods and parameters for verifying R&M requirements are also detailed in Section 4 of the specification before it is authenticated. Establishing a Joint R&M Evaluation Team (JRMET) for each program is also crucial to a successful R&M program.

6.6.1 Test and Evaluation Master Plan (TEMP). The TEMP is drafted early in the conceptual phase by the SPO and the using/supporting/testing commands to outline the major elements of the test program (critical issues, test resources, timing and location). The TEMP critical issues are usually separated into two major themes: operational effectiveness and operational suitability. Operational effectiveness is concerned with how well the system operates in its intended environment-this is the operations part of the test. Operational suitability is concerned with how well the system can be supported and whether or not it is ready to perform its intended mission-this is the logistics support part of the test. R&M are critical parts of the operational suitability test objective and should evaluate if the system meets the operational values contained in the SORD's Requirements Correlation Matrix (RCM). The TEMP should be reviewed/coordinated by AFSPACECOM/LKYY to insure it contains the proper R&M parameters.

6.6.2 Joint R&M Evaluation Team (JRMET). The JRMET is held regularly by the SPO's Systems Engineering Logistics Branch to review the TEMP, test plans and test data, establish proper data collection and data management procedures, correct deficiencies in data and, in general, ensure the R&M program is successfully completed. The JRMET will draft a charter outlining its functions and describing the responsibilities of each member.

AFSPACECOM/LKY will normally attend these meetings as part of the logistics effort. The JRMET should also be attended by Command engineering personnel. The JRMET is a major avenue of addressing and raising issues on R&M during system acquisition, since all the key players (SPO, AFOTEC, AFLC, AFSPACECOM and the contractor) are in attendance.

## 7.0 R&M IN THE TESTING PROCESS

Section 6.6 discussed the importance of preparing for testing and the role of the JRMET. R&M testing is part of the two major test efforts. Development Test and Evaluation and Initial Operational Test and Evaluation continue throughout FSD,production deployment, and Operational Support Phases. The testing process reaches a high degree of detail in system/ subsystem testing, which includes the support elements of the system. The test and evaluation tasks are the primary means to verify achievement of program objectives and justify the continued or increased commitment of resources to the program.

### 7.1 DEVELOPMENT TEST & EVALUATION (DT&E)

DT&E is the responsibility of the SPO. It tests system performance against system specifications to determine if the contractor has successfully implemented the required design. The DT&E test plan is written by the SPO and is supported by the contractor prepared/government approved DT&E test procedures. While the DT&E test environment is usually much more restrictive than the operational environment, the R&M data collected provides an initial data base of R&M experience. This data is passed to the JRMET for review, classification and analysis. An initial assessment of system R&M values is determined and corrective action initiated.

### 7.2 OPERATIONAL TEST & EVALUATION (OT&E)

OT&E provides the capability to track and evaluate the system's initial operational R&M performance; identify any deficiencies; and correct them through changes in design, technical data, software, support equipment, manning, training, or supply support. The OT&E process includes three primary areas: test planning, test execution and test reporting.

7.2.1 Test Plans. OT&E test plans are written by AFOTEC (with assistance from the using/developing/supporting commands) if AFOTEC is conducting the test. AFSPACECOM will write the test plan if AFOTEC is monitoring the test. The test plans should show the test objectives, criteria and methodology that will be used to evaluate the R&M values outlined in the TEMP. The R&M values provide the core of the operational suitability evaluation, so it is important that adequate test planning be conducted prior to the test. Again, AFSPACECOM/LKYY can provide assistance in reviewing the test plans for consistency with the test objectives and in determining if the projected test data will provide adequate confidence in the test results.

7.2.2 <u>Test Execution</u>. Test execution is the actual test period during which the data is collected to make the final test report. The test is normally conducted using the contractors' test descriptions. Two of the tests are the reliability and maintainability demonstrations. The reliability demonstration is conducted to test how well the system performs without failure in the operational environment. The maintainability demonstration is conducted to evaluate the relative ease with which the design can be supported, verify maintainability requirements, and evaluate the effectiveness of fault detection/fault isolation. When the FSD objectives have been attained, the program reaches the production/acceptance decision.

7.2.3 <u>Test Reporting</u>. The production/acceptance decision is supported by the OT&E test report. As in 7.2.1 above, whoever wrote the test plan (AFOTEC or AFSPACECOM) will write the test report. The test report details achieved R&M, explains any limitations that caused the test data to be less than what was desired, and identifies deficiencies in the achieved R&M versus the R&M standards described in the test plans.

# 8.0 R&M IN THE OPERATIONAL ERA

R&M tracking continues into the operational era with Follow-on OT&E (FOT&E) and maintenance data collection (MDC).

## 8.1 FOLLOW-ON OPERATIONAL TEST & EVALUATION (FOT&E)

FOT&E is conducted to test objectives not fully completed in OT&E, validate OT&E results and test corrections to deficiencies uncovered during OT&E. The production contract includes the requirement to prevent previously demonstrated levels of R&M performance from being degraded and ensure that R&M is verified periodically during the production run. Successful R&M demonstration is a condition of acceptance of production articles. Some programs may contain Reliability Improvement Warranties (RIWs) to incentivize production contractors to improve system reliability. By correcting design problems or defects that reduce system reliability, the contractor can reduce costs incurred by contract warranty clauses.

## 8.2 MAINTENANCE DATA COLLECTION (MDC)

MDC is the system whereby the maintenance downtime is tracked and analyzed so that actual R&M performance can be determined. AFSPACECOM/LKM is the OPR for MDC. MDC should be performed even though the system is contractor maintained. This allows AFSPACECOM to evaluate contractor as well as system performance. This data is used to determine trends in maintenance and project when the system needs to be replaced or modified. It's important during this phase to ensure that standardized (both in form and method of delivery) MDC requirements are placed on all contracts for maintenance and logistics support in the operational era. The Air Force Standard MDC system is the Core Automated Maintenance System (CAMS).

## 9.0 SUMMARY

Establishing realistic and consistent R&M parameters in SONs and SORDs is critical to fielding a system that will meet our operational requirements and be logistically supportable. Your responsibility for R&M does not stop with these requirements documents. Translation of operational and logistics support requirements into contractual clauses is necessary. This translation is a primary responsibility of the System Program Office; the using command is responsible for assisting in this effort.

The R&M requirements and deliverables specified in the system specifications, statement of work, and contract data requirements list must be closely examined by the using command. Tracking R&M allocation through specification and design reviews is especially important.

Testing R&M parameters is an integral part of DT&E and IOT&E efforts. DT&E basically tests contract R&M parameters; IOT&E tests operational R&M parameters.

Continued emphasis on and attention to R&M are required throughout the life cycle of the system. Once the system is fielded, R&M data must be collected through a standard maintenance data collection system and subsequently analyzed to identify any R&M problems. Corrective action up to and including system replacement will be evaluated. This analysis may even be used to justify the preparation of a new SON/SORD.

# APPENDIX A

# R&M PRIMER

## RELIABILITY AND MAINTAINABILITY

## PRIMER

### 1.0 INTRODUCTION

The purpose of this primer is to provide the action officer an overview of the concepts, terminology and relationships used in Reliability and Maintainability (R&M). It is not designed to make the action officer an R&M engineer. The terms and definitions used are taken from MIL-STD-721C, AFSPACECOM/LKY Technical Report 88-1, and various R&M texts.

This primer starts with an explanation of basic R&M concepts. Next these basic concepts are expanded and refined to include mission and logistics R&M parameters.

### 2.0 BASIC CONCEPTS

This section defines the basic concepts of reliability and maintainability, introduces item level R&M terms, and shows how to do rudimentary R&M calculations. These terms are not to be used to state system level operational R&M requirements.

2.1 Reliability Reliability is the duration or probability of failure free performance under stated conditions. It can also be defined as the probability an item can perform its intended functions for a specified interval under stated conditions.

2.1.1 Mean Time Between Failures (MTBF) A basic quantitative measure of reliability is Mean Time Between Failures (MTBF). This is the expected length of time a system will be operational between failures. It is normally calculated by taking the number of operational hours in a stated period and dividing it by the number of failures. MTBF could be expressed in other life units such as number of cycles, number of orbits, or number of landings.

2.1.2 Failure Rate Failure rate is defined as the number of failures of an item per measure of life units (e.g., failures per million hours, failures per 1000 cycles). The failure rate is simply the reciprocal of the MTBF. If the average time between failures is 1,000,000 hours (i.e., MTBF = 1,000,000), then the failure rate is 1 failure per 1,000,000 hours or 0.000001 failures per hour. In some computations failure rates are simpler to use than the associated mean (average) value.

2.1.3 Mission Reliability (MR) The second definition of reliability stated in paragraph 2.1 includes the added factor of operating "for a specified interval". Instead of determining the

average time between failures or the number of failures per hour, Mission Reliability (MR) deals with the probability of the item working continuously without a failure for a specified period of time. The term most commonly used for the specified time period is Mean Mission Duration. The second factor affecting MR is MTBF. The mathematical equation for MR for most electronic items is:

$$MR = e^{-MMD/MTBF}$$

Where: e = base of natural logarithms = 2.71828
MTBF = Mission Time Between Failures
MMD = Mean Mission Duration

This is the most difficult mathematical equation we will use in this primer; most hand held scientific or business calculators will easily handle this equation. An interesting note about MR: if you design a system with a MTBF equal to the length of the average mission (i.e., MTBF = MMD), the probability of surviving that mission is only 36.8%. Mission Reliability will be further discussed in Section 3.6.

2.2 Maintainability is defined as a characteristic of a design that determines the type and amount of maintenance required to retain that design in, or restore it to, a specified condition. Maintenance required to retain an item in its designed condition is normally called Preventive Maintenance (PM) since it prevents a failure from occurring. Maintenance required to restore an item is normally called Corrective Maintenance (CM) since it corrects some fault in the system.

2.2.1 Mean Time To Repair (MTTR) The basic measure of item maintainability is Mean Time To Repair (MTTR). MTTR is calculated by dividing the number of times an item required repair into the total length of time required to make those repairs. MTTR includes active maintenance time only. It does not include any delay time (e.g., time spent waiting for parts).

2.2.2 Administrative and Logistics Delay Time (ALDT) There are factors external to the item design that affect the actual time taken to perform maintenance. Some of these factors are the time required for the technician to arrive at the failed item, time spent waiting for tools or equipment to test the item, and time spent waiting for parts. The delays caused by these external factors are generically called Administrative and Logistics Delay Time (ALDT).

2.2.3 Mean Down Time (MDT) It is often important to know the time required to restore a failed item including expected delays. Mean Down Time (MDT) is the term used for this. MDT is the sum of the active maintenance time plus administrative and logistics delays (i.e., MDT = MTTR + ALDT).

2.3 Availability The probability an item is available for use is a function of how often it breaks and how long it takes to repair. The formal definition of availability is "a measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at any random time. Availability is sometimes referred to as the up time ratio. Simplistically it is Uptime/Total Time or Uptime/(Uptime + Downtime). Uptime is a measure of the item's reliability and downtime a measure of its maintainability.

2.3.1 R&M Trade Offs There are many combinations of R&M values which could yield the same Availability value. For example an item that is up (operational) 100 hours and down (failed) 1 hour has the same availability as an item up 400 hours and down 4 hours [100/(100+1) = 400/(400+4)]. It may be unacceptable for the item to fail more frequently than every 200 hours or to take more than four hours to repair. For this reason it's necessary to specify more than just the item's availability. Figure 2-1 shows graphically the interrelationship among reliability, maintainability and availability.

***RELIABILITY - MAINTAINABILITY TRADEOFFS***

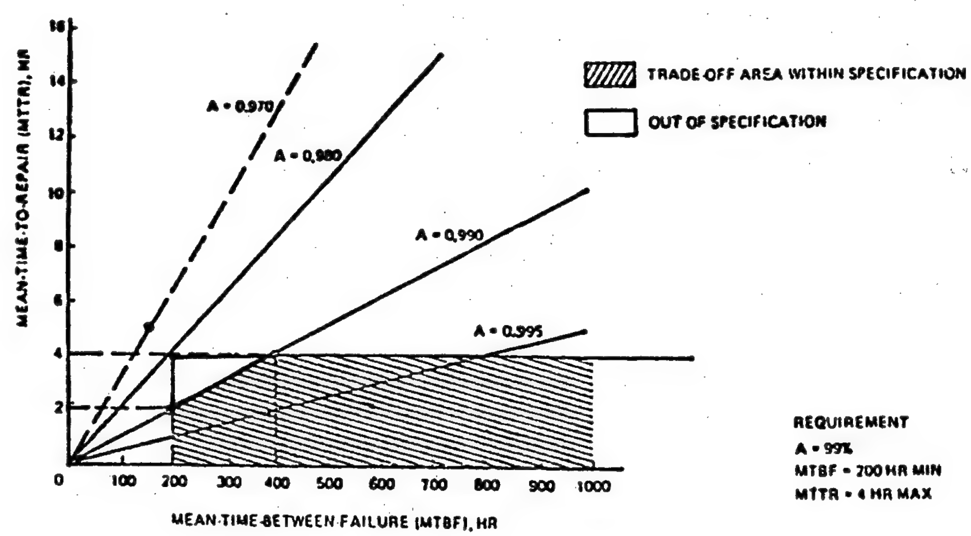



***Figure 2-1***

2.3.2 Inherent Availability (Ai) Availability can refer to the inherent capability of the item, independent of the support infrastructure. This type of availability is referred to as inherent availability (Ai). The measure used for Uptime is normally MTBF. The measure used for Downtime is MTTR. The resultant formula is Ai = MTBF/(MTBF + MTTR).

2.3.3 Operational Availability (Ao) To determine the availability expected in the normal operating environment, it becomes necessary to account for the impact of support delays. This type of availability is called operational availability (Ao). The factor used for Uptime if we assume there is no interfering preventive maintenance, is the same one used in Ai (i.e., MTBF). The Downtime factor used is Mean Down Time (MDT) which equals MTTR + ALDT. The formula is Ao = MTBF/(MTBF + MDT).

2.4 Series/Parallel Models The previous sections introduced the basic R&M concepts as applied to individual items. Items are normally combined to perform more complex functions. The way they are combined affects the reliability of that combination. Items can be combined in series or in parallel.

2.4.1 Series Reliability When units are combined in such a way that a function must be successfully performed by the first unit before the second unit can perform its function and so on, the units are said to be combined in a series configuration. Figure 2-2 is a typical series reliability block diagram.

***SERIES RELIABILITY***

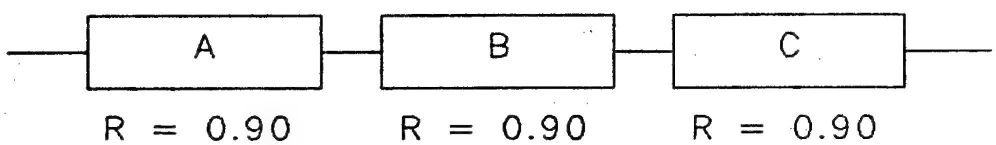



***Figure 2-2***

In figure 2-2, a function requires items A, B, and C to operate. Assume each block has a probability of operating of 0.90. To find the probability of completing that function, we must consider the probability of A, B, and C each working. Mathematically we do this by multiplying the reliability of each item (i.e., Ra, Rb, & Rc). The formula for this set of three components is "Rs = Ra x Rb x Rc. In this case the resultant reliability is only 72.9% (i.e., 0.9 x 0.9 x 0.9).

As this example indicates, even though individual items may have good reliability, their serial combination results in a significantly lowered reliability.

2.4.2 Parallel Reliability There is a way to combine items so that the combined reliability is better than the individual reliabilities. When items are tied together so their function can be performed by any one (or more) of them, they are said to

be in parallel. Figure 2-3 is a typical parallel reliability block diagram.

***PARALLEL RELIABILITY***

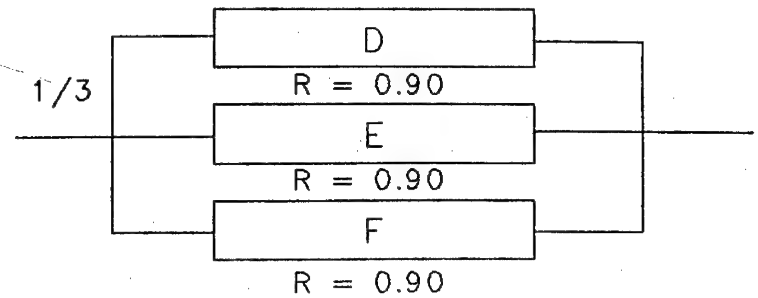



***Figure 2-3***

In Figure 2-3, as indicated by the 1/3, only one of the three items must be working for the function to be performed. In other words the function fails only when all three items fail simultaneously. We can find the probability of this happening by multiplying the individual probabilities of failing.

Let's assume items D,E, and F each have a probability of not failing (Reliability) of 0.90. Since the probability of failing added to the probability of not failing must equal one, the probability of failing equals 0.10, (i.e., 1 - 0.9). The chance of all three items failing is 0.1 x 0.1 x 0.1 = .001. Since we now know the probability of all three failing, we subtract it from one to get the probability of one or more not failing (1.0 - 0.001 = 0.999). So in this configuration, the probability of the function being performed is 0.999.

Putting this logic into a formula we get:

If reliability of D is Rd then its unreliability is 1 - Rd
If reliability of E is Re then its unreliability is 1 - Re.
If reliability of F is Rf then its unreliability is 1 - Rf.

The probability of D, E, & F failing is (1-Rd)(1-Re)(1-Rf).
The probability of D, E, & F not failing (Rs) is

$$Rs = 1 - [(1-Rd)(1-Re)(1-Rf)]$$

It's also possible to put items in parallel and require more than one to remain operational. Computing the probability of the function being performed requires the use of complex mathematical computations outside the scope of this primer.

2.4.3 <u>Series/Parallel Combinations</u> In more complex configurations there are often combinations of series and parallel items. In these cases it is relatively simple to reduce

each set of parallel items to an equivalent series block and use that block as shown in Figures 2-4 and 2-5.

***ORIGINAL DIAGRAM***

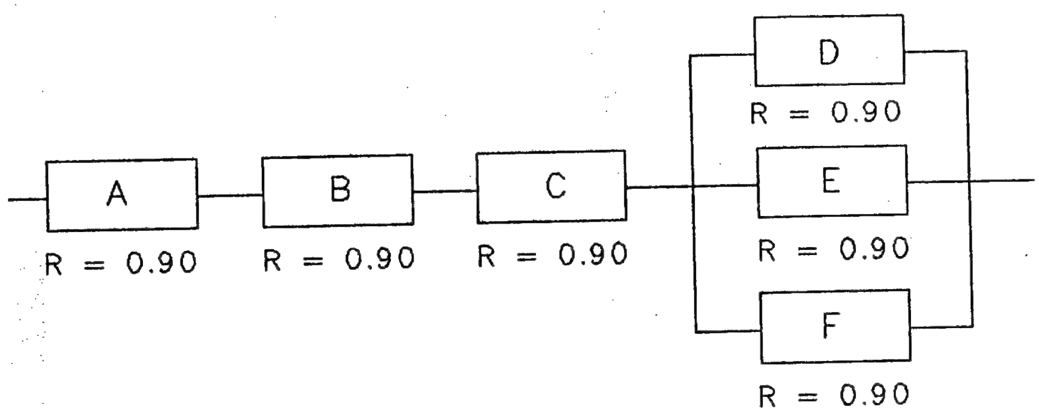
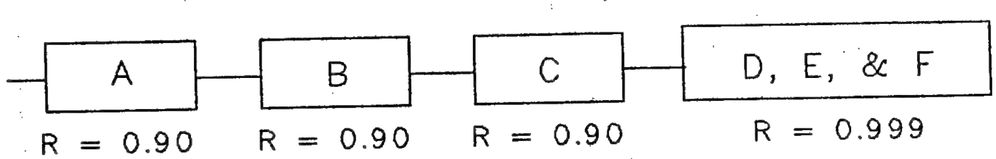



***Figure 2-4***

***EQUIVALENT DIAGRAM***




Rs = 0.728

***Figure 2-5***

## 3.0 MISSION R&M

The concepts introduced in section two are basic, component level concepts. These concepts can be applied to system level requirements with some minor modifications and expansions. This section will define the R&M terms for use in defining operational requirements in Statements of Operational Need (SONs) and System Operational Requirements Documents (SORDs). These terms are especially adaptable for use with space, space surveillance and missile warning systems.

3.1 <u>Mission Effectiveness (ME)</u> System capability has two factors associated with it. The first factor is the probability of a system being operable and capable of initiating a mission at any (random) time. The second factor is the probability that a system is operable and capable at any (random) time during a mission. If these two probabilities are expressed in consistent terms, then the probability of effectively completing the mission is the product of the two factors.

The first factor is the traditional definition of system availability. The second factor is a measure of how dependable a system is once a mission has begun. In this context, availability is associated with non-mission time and dependability with mission time. Since the system is frequently inactive or exercised differently during non-mission time, there are different non-mission and mission reliability and maintainability factors associated with it. Figure 3-1 shows the relationships among these factors.

***SYSTEM TIME VERSUS R&M PARAMETERS***

<table>
<tr><td colspan="3">MISSION EFFECTIVENESS<br>(TOTAL TIME)</td></tr>
<tr><td colspan="2">AVAILABILITY<br>(NON-MISSION TIME)</td><td>DEPENDABILITY<br>(MISSION TIME)</td></tr>
<tr><td>INACTIVE TIME</td><td>ACTIVE TIME</td><td>ACTIVE TIME</td></tr>
</table>

***Figure 3-1***

3.2 <u>Availability & Dependability</u> The terms availability and dependability are not new. These terms are listed in MIL-STD-721C, Definition of Terms for Reliability and

Maintainability. Although the term availability has always been defined as the probability of being operable and capable at any (random) time of initiating a mission, it has often been used to calculate the probability of the system working at any (random) time during a mission.

The terms and concepts of availability and dependability are also well documented in standard logistics engineering and reliability texts. Examples are Benjamin S. Blanchard's 2nd edition of Logistics Engineering and Management, Page 20, and Igor Bazovsky's Reliability Theory and Practice, Chapter 17.

Misuse of the term availability hasn't created many problems in the aircraft world because frequently only mission time is involved. However, if we are to effectively account for the unique R&M parameters associated with spacecraft launch, on orbit mission, and space vehicle turn around, a return to the more accurate definitions is required.

3.3 Mission Time R&M Parameters The R&M parameters associated with non-mission time can be inherently different from those with mission time (e.g., Age deterioration of seals versus wearout failures). MIL-STD-721C defines the reliability and maintainability parameters associated with dependability (mission time) as Mission Time Between Critical Failures (MTBCF) and Mission Time To Restore Functions (MTTRF). As their titles indicate, they are only concerned with the impact on mission. This makes them ideal for stating operational requirements and for documenting results of operational testing.

3.3.1 Mission Time Between Critical Failures (MTBCF) The definition of Mission Time Between Critical Failures from MIL-STD-721C is: A measure of mission reliability. The total amount of mission time, divided by the total number of critical failures during a stated series of missions. Its formula is:

$$MTBCF = \frac{\text{TOTAL MISSION TIME}}{\text{\# OF CRITICAL FAILURES}}$$

3.3.2 Mission Time To Restore Functions (MTTRF) The definition of Mission Time To Restore Functions is: A measure of mission maintainability. The total maintenance time required to restore mission functions interrupted by critical failures divided by the number of critical failures during the course of a specified mission profile. MTTRF includes both scheduled and unscheduled maintenance. Its formula is:

$$MTTRF = \frac{\text{TOTAL RESTORAL TIME}}{\text{\# OF CRITICAL FAILURES}}$$

When MTTRF is used to calculate Operational Dependability (Do)

versus Inherent Dependability (Di), Administrative and Logistics Delay Time (ALDT) is included as part of total restoral time.

3.3.3 <u>Maximum Mission Time To Restore Functions (MaxTTRF)</u> If only the mean MTTRF value is specified, there may be a wide range of individual repair time values. Figure 3-2 shows two repair time distributions with the same mean value. The lower curve has a greater variation around the mean value. Two systems could be designed to meet the same mean MTTRF specification and not necessarily meet operational requirements. A system design which follows the lower distribution will have more failures that take longer to repair than one whose design fits the upper curve. This could result in repairs taking longer than is operationally acceptable, on too frequent a basis.

***REPAIR TIME DISTRIBUTIONS WITH THE SAME MEAN BUT WITH DIFFERENT VARIANCE***

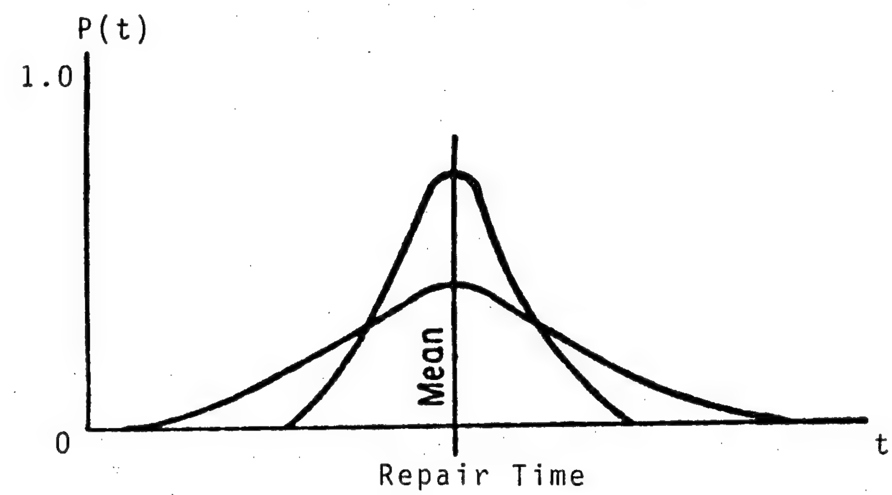



***Figure 3-2***

Because of this, it may become necessary to place restrictions on the maximum amount of time the system must be restored within. This can be done by specifying a Maximum Time To Restore Functions (MaxTTRF) at a stated percentile. For example, you could specify that 90% of all repairs be accomplished in 2 hours or less. This parameter is sometimes referred to as Maximum Continuous Downtime.

3.3.4 <u>MaxTTRF and Availability/Dependability</u> As seen earlier in this primer, availability and dependability are normally based on mean values. If we know the maximum time we want the system repaired in, we need a way to find the mean value for use in these calculations. There is a relationship between the mean and maximum values for a given distribution. By knowing what the underlying distribution is, we can calculate the mean value. For

more information on how to convert mean and max values, see Section 3.5 on distributions.

3.4 Non-mission Time R&M Parameters During non-mission time it is possible to have active and inactive time. There can be inherent characteristics of the system that affect R&M parameters during these times. Under certain circumstances, it may be logical to separate the R&M factors associated with **inactive** non-mission and **active** non-mission time. However, under normal circumstances it usually is adequate to address non-mission time R&M factors as a single entity.

3.4.1 Mean Time Between Downing Events (MTBDE) A downing event is any event during non-mission time that affects the system's ability to initiate a mission. Scheduled interfering preventive maintenance or servicing actions required to maintain the system in a state capable of initiating a mission are examples of downing events. MIL-STD-721C calls MTBDE the reliability parameter associated with readiness.

The definition of MTBDE is: A measure of system reliability associated with availability. The total non-mission time divided by the # of downing events. It formula is:

$$\text{MTBDE} = \frac{\text{TOTAL NON-MISSION TIME}}{\text{\# OF DOWNING EVENTS}}$$

3.4.2 Mean Time To Restore System (MTTRS) The collateral maintainability criteria associated with readiness is Mean Time To Restore System (MTTRS). MTTRS applies only to maintenance actions that occur during non-mission time. MTTRS includes both scheduled and unscheduled maintenance actions.

The definition of MTTRS is: A measure of system maintainability associated with availability. The total maintenance time associated with downing events divided by the number of downing events. Its formula is:

$$\text{MTTRS} = \frac{\text{Total Restoral Time}}{\text{\# of Downing Events}}$$

When MTTRS is used to calculate Operational Readiness (Ro) versus Inherent Readiness (Ri), total restoral time includes Administrative and Logistics Delay Time (ALDT).

3.5 Distributions Failure rates and repair times tend to follow a general pattern for specific types of systems. The general pattern followed fits a specific statistical distribution.

3.5.1 Failure Rate Distributions There are three basic types of failures for communication-electronic systems. These are burn-in

failures, random failures and wear out failures. Burn-in failures are normally screened out by testing or environmental stress screening prior to placing the system in field operation. During the burn-in period, the failure rate normally decreases; random failures occur during the useful life period. The failure rate during the useful life period remains relatively constant. During the wearout period the failure rate increases. These three types of failure rates are shown graphically in Figure 3-3. This particular curve is commonly known as the bathtub curve.

***COMPONENT FAILURE RATES AS A FUNCTION OF TIME***

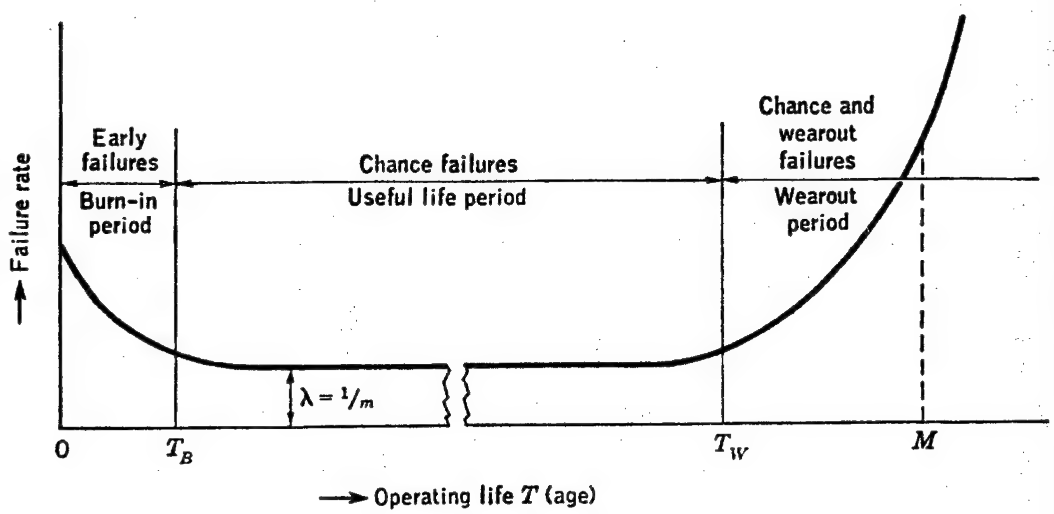



***Figure 3-3***

Since burn-in failures normally occur during the development/ production phase, we are only concerned about random and wearout failures in this primer.

3.5.1.1 <u>Exponential Failure Distribution</u> Failures during the useful life period for communication-electronic components follow an exponential distribution. With this type of distribution, 63.2 percent of the failures will occur before the mean value. From another perspective the mean value will be met or exceeded only 36.8 percent of the time. Figure 3-4 is a graph of the exponential probability density function.

3.5.1.2 <u>Normal Failure Distribution</u> Component failures caused by wearout follow a normal distribution. Figure 3-5, shows the normal wearout of a lamp. The average life expectancy for this particular lamp is 7200 hours. A constant level of random failures would be expected during the useful life period. Once the useful life period is over (around 5000 hours), the lamps will start experiencing wearout failures. By 7200 hours we would expect half the lamps to have failed. The other half would fail

after 7200 hours. The rate of failure would be symmetrical around the mean value.

**EXPONENTIAL FAILURE FUNCTION**

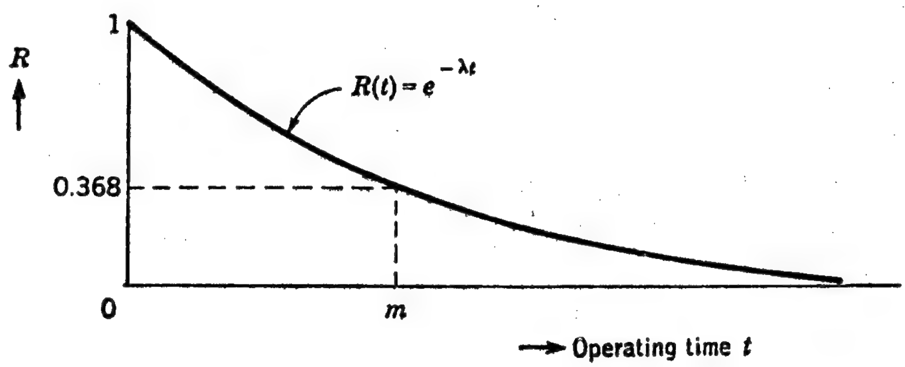



*Figure 3-4*

**WEAROUT FAILURES WITH A NORMAL DISTRIBUTION**

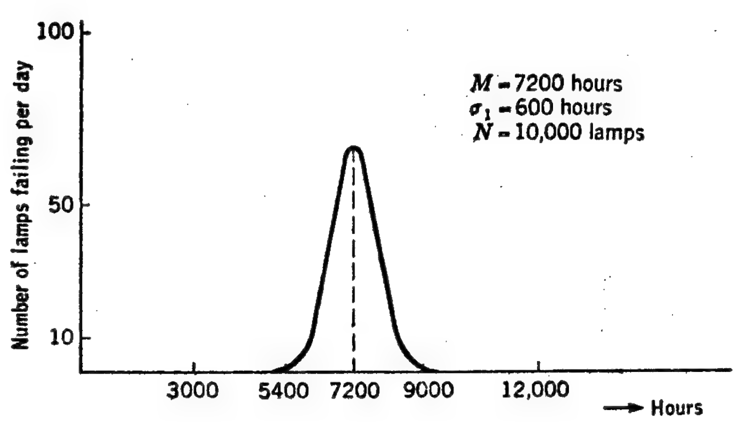



*Figure 3-5*

3.5.2 <u>Restoral Time Distributions</u> Like failure rates, restoral times also tend to follow specific patterns or distributions. For communication-electronic systems three types of distributions are commonly found. The type of maintenance actions required to restore the system affects which of the three is appropriate.

3.5.2.1 <u>Exponential Repair Distributions</u> When system restoral is primarily accomplished by a combination of manual and automatic switchover to a redundant unit, an exponential distribution is normally followed. This curve is shown in Figure 3-6. As seen from this graph, the majority of items can be repaired within a short restoral time with fewer restoral actions occurring as repair time increases. As with the exponential failure rate curve, 62.8 percent of the repair actions will be accomplished before the mean repair time is reached.

***EXPONENTIAL REPAIR FUNCTION***

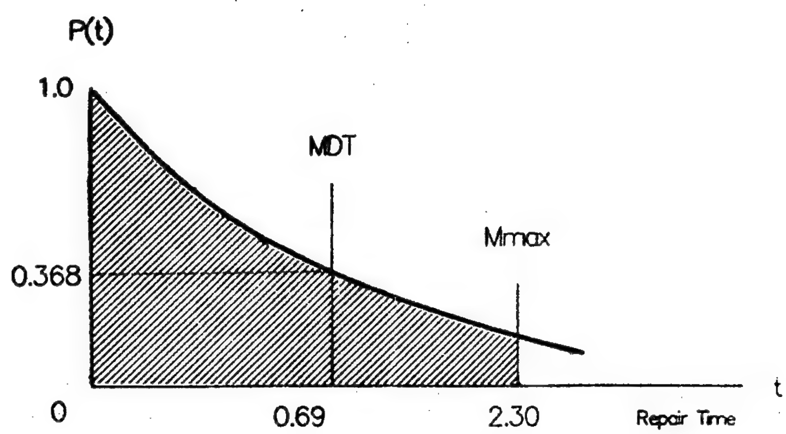



***Figure 3-6***

Mean (MDT) and maximum (Mmax) allowable downtimes are shown in Figure 3-6. The 0.69 sigma indicates the number of standard deviations the mean is away from the origin (time zero). The 2.30 sigma is the number of standard deviations the 90th percentile is away from the origin. The hatched area indicates repair times that are equal to or less than the maximum allowable down time.

From this information we can establish a ratio between the mean and maximum values. For instance, if we want 90 out of 100 repair actions to be accomplished in 1 hour or less, a mean value of 0.30 hours [(0.69/2.30) (1 hour)] is expected. Similarly, if

we specify a mean value of 1 hour, 90 out of 100 repair actions will be accomplished within 3.33 hours [(2.30/0.69) (1 hour)].

3.5.2.2 <u>Log-Normal Repair Distributions</u> When system restoral is accomplished primarily by a combination of switchover and on-equipment repair, a Log-Normal distribution is often seen. Figure 3-7 depicts a typical Log-Normal probability density function with mean (MDT) and maximum (Mmax) allowable downtime shown. The 0.8 sigma indicates the number of standard deviations the mean is away from the origin (time zero). The 1.86 sigma is the number of standard deviations the 90th percentile is away from the origin. The hatched area indicates repair times that are equal to or less than the maximum allowable down time.

***LOG-NORMAL REPAIR DISTRIBUTION***

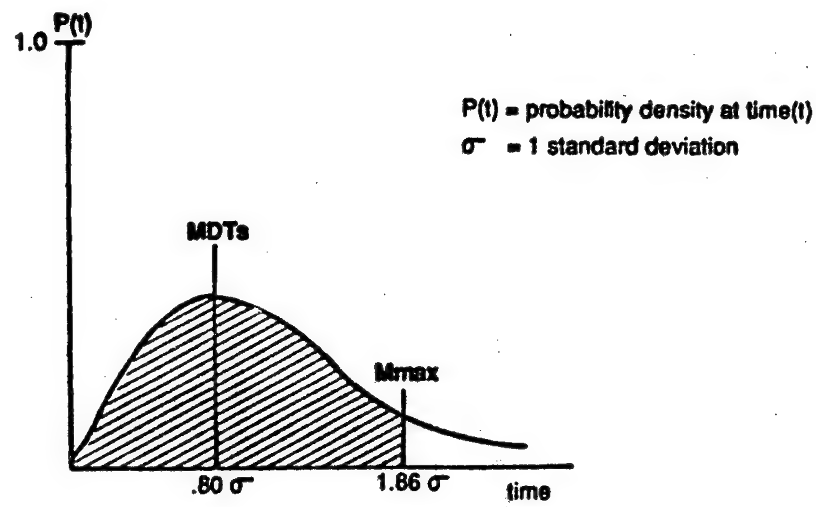



***Figure 3-7***

From this information we can establish a ratio between the mean and maximum values. For instance, if we want 90 out of 100 repair actions to be accomplished in 1 hour or less, a mean value of 0.43 hours [(0.80/1.86) (1 hour)] is expected. Similarly, if we specify a mean value of 1 hour, 90 out of 100 repair actions will be accomplished within 2.325 hours [(1.86/0.80) (1 hour)].

3.5.2.3 <u>Normal Repair Time Distribution</u> When system restoral is accomplished primarily by on-equipment repair actions with associated administrative and logistics delays, a normal distribution is usually found. As with the normal failure rate distribution, 50 percent of the repair actions will be accomplished before the mean value and 50 percent after. The normal probability density function including mean (MDT) and maximum (Mmax) allowable downtime for repair actions is shown in

Figure 3-8. The 3.0 sigma indicates the number of standard deviations the mean is away from the origin (time zero). The 4.28 sigma is the number of standard deviations the 90th percentile is away from the origin. The hatched area indicates repair times that are equal to or less than the maximum allowable down time. As with the exponential and log-normal distributions, we can establish a ratio between the mean and maximum values. For instance, if we want 90 out of 100 repair actions to be accomplished in 1 hour or less, a mean value of 0.70 hours [(3.00/4.28) (1 hour)] is expected. Similarly, if we specify a mean value of 1 hour, 90 out of 100 repair actions will be accomplished within 1.43 hours [(4.28/3.00) (1 hour)].

***NORMAL REPAIR DISTRIBUTION***

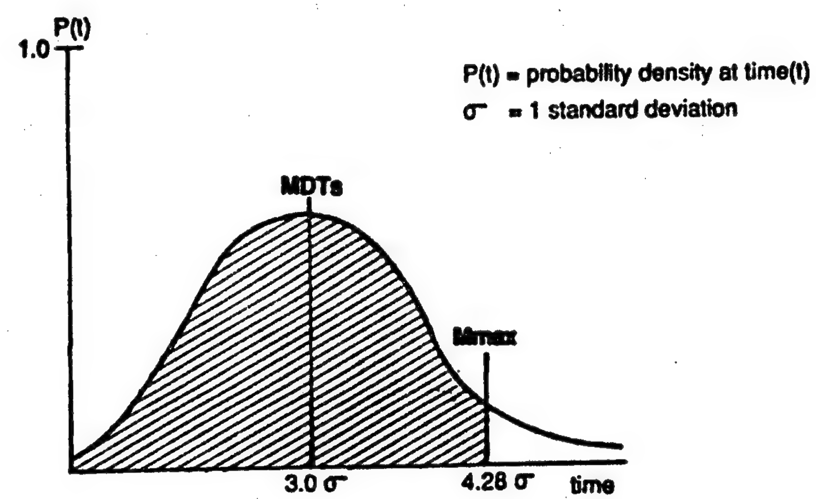



***Figure 3-8***

3.5.3 <u>Mean/Maximum Conversions</u> If operational considerations require a specified maximum allowable downtime, the above transformations become especially useful. It is possible to specify percentile values other than the 90th percentile but usually not feasible to design a system so that 100% of all possible failures can be repaired in a stated period. The 90th percentile is normally used because it represents an efficient tradeoff between cost and repair time.

AFOTEC has collected and analyzed repair time data from a multitude of communication-electronic systems. After applying curve fitting techniques, they have found that the log-normal distribution typifies these systems. With this assumption we can make a reasonable approximation of the mean value associated with specific maximum values.

### 3.6 Mission Reliability (MR)

The concept of mission reliability that was discussed in the basic concepts section can be applied directly at the system level. Instead of MTBF, the term Mission Time Between Critical Failures (MTBCF) is used. Mission reliability is a measure of system reliability during mission time. It does not take into account system maintainability or availability factors.

There are many missions and systems which do not allow restoral of specific functions during the mission. Consider the example of a spacecraft oxygen or propulsion system. If a critical failure occurs, it may not be possible to restore the system prior to running out of oxygen or in time to achieve orbit. It then becomes an operational requirement to achieve a stated reliability for a stated mission duration.

The definition of Mission Reliability (MR) is: A measure of the degree to which a system is operable and capable of performing its required functions at a specified time into a mission or for a mission of stated duration. It is based on the effects of mission reliability during mission time only.

The concept of mission reliability is based on the mathematical probability of survival function. The formula for mission survivability will vary based on the underlying distribution of mission critical failures. For an exponential distribution the formula for MR is:

$$MR = e^{-MMD/MTBCF}$$

Where: e = base of natural logarithms
MTBCF = Mission Time Between Critical Failures
MMD = Mean Mission Duration

3.7 Mission Versus Logistics Parameters The R&M parameters discussed above deal with the effects on mission accomplishment. They are of prime importance to the operational commands. The operational commands are also very concerned with a second set of R&M parameters that deal with logistics support related terms. These parameters have significant impact on command manpower and supply support. Section 4 of this primer addresses these factors.

## 4.0 LOGISTICS R&M

Although mission R&M parameters are an indication of the capability of the system to perform specified mission profiles, they are not the only ones operational commands are concerned with. This section will address the R&M parameters associated with logistics support and their impact on the operational command.

4.1 <u>Maintenance Concerns</u> The operational command is concerned with R&M factors that affect maintenance. Of special interest are the areas of maintenance manpower and maintenance cost. These parameters may be used in requirements documents when they specify operational constraints the system must be designed within. An example is a system that must be designed to be maintained with the same or fewer number of personnel as the system it replaces due to manpower ceiling limitations. Another example is a contractor maintained system whose Operations and Maintenance (O&M) budget must not exceed programmed contract maintenance funds.

4.2 <u>Mean Time Between Maintenance (MTBM)</u> Regardless of the impact on mission effectiveness, every maintenance action can have an impact on maintenance manning. The number of maintenance actions and the length of time to perform the average maintenance action combine to determine the basic manpower requirement. The reliability term associated with maintenance manning is Mean Time Between Maintenance (MTBM).

Since the purpose of this term is to determine the impact on maintenance manpower and cost, all maintenance actions should be considered. This includes mission/non-mission time as well as scheduled/unscheduled maintenance actions.

The definition of MTBM is: A measure of system reliability taking into account maintenance policy. The total number of system life units in a stated period of time divided by the number of maintenance events both scheduled and unscheduled. The formula is:

$$\mathrm{MTBM} = \frac{1}{\dfrac{1}{\mathrm{MTBSM}} + \dfrac{1}{\mathrm{MTBUM}}}$$

Where: MTBSM = Mean Time Between Scheduled Maintenance
MTBUM = Mean Time Between Unscheduled Maintenance

Since the frequency of MTBSM and MTBUM may vary, it is necessary to convert then to rates, add them, and take the reciprocal.

4.2.1 <u>Mean Time Between Scheduled Maintenance (MTBSM)</u> Mean Time Between Scheduled Maintenance is the term used to indicate the average frequency of scheduled maintenance events. The term "preventive maintenance" is frequently used to denote these types of maintenance events. Preventive maintenance has the connotation of actions taken specifically to prevent a failure. On certain space and missile warning systems, routine servicing activities (e.g., refueling of a satellite) may occur. In some respects these servicing actions are not preventive maintenance actions. For this reason, the use of the more generic term scheduled maintenance is proposed.

The definition of Mean Time Between Scheduled Maintenance (MTBSM) is: A measure of system reliability taking into account maintenance policy. The total relevant system time divided by the number of scheduled maintenance events. The formula for MTBSM is:

$$\text{MTBSM} = \frac{\text{TOTAL SYSTEM TIME}}{\text{\# OF SCHEDULED MAINTENANCE EVENTS}}$$

4.2.2 <u>Mean Time Between Unscheduled Maintenance (MTBUM)</u> Mean Time Between Unscheduled Maintenance is the term used to denote the average frequency of unscheduled maintenance events. The term unscheduled maintenance is proposed instead of corrective maintenance for two reasons. The first reason is that certain preventive maintenance events (e.g., repainting for corrosion control) are done on an as required (i.e., unscheduled) basis. The second reason is to be consistent with the term scheduled maintenance.

The definition of Mean Time Between Unscheduled Maintenance (MTBUM) is " A measure of system reliability taking into account maintenance policy." The total relevant system time divided by the number of unscheduled maintenance events. The formula for MTBUM is:

$$\text{MTBUM} = \frac{\text{TOTAL SYSTEM TIME}}{\text{\# OF UNSCHEDULED MAINTENANCE EVENTS}}$$

4.3 <u>Mean Maintenance Time (MMT)</u> While MTBM, MTBSM, and MTBUM are measures of system reliability, each have a collateral measure of system maintainability. The collateral maintainability term for MTBM is Mean Maintenance Time (MMT).

The definition of MMT is: A measure of system maintainability considering maintenance policy. The sum of unscheduled and scheduled maintenance times divided by the sum of scheduled and unscheduled maintenance events during a stated period of time. The formula is:

$$MMT = \frac{\text{SCHEDULED + UNSCHEDULED MAINTENANCE TIME}}{\text{\# OF SCHEDULED + UNSCHEDULED MAINTENANCE EVENTS}}$$

4.3.1 Mean Scheduled Maintenance Time (MSMT) The maintainability parameter associated with Mean Time Between Scheduled Maintenance (MTBSM) is Mean Scheduled Maintenance Time (MSMT). The definition of MSMT is: A measure of system maintainability taking into account maintenance policy. Total scheduled maintenance time divided by the number of scheduled maintenance events during a stated period of time. The formula is:

$$MSMT = \frac{\text{TOTAL SCHEDULED MAINTENANCE TIME}}{\text{\# OF SCHEDULED MAINTENANCE EVENTS}}$$

4.3.2 Mean Unscheduled Maintenance Time (MUMT) The maintainability parameter associated with Mean Time Between Unscheduled Maintenance (MTBUM) is Mean Unscheduled Maintenance Time (MUMT). The definition of MUMT is: A measure of system maintainability considering maintenance policy. Total unscheduled maintenance time divided by the number of unscheduled maintenance events. The formula is:

$$MUMT = \frac{\text{TOTAL UNSCHEDULED MAINTENANCE TIME}}{\text{\# OF UNSCHEDULED MAINTENANCE EVENTS}}$$

4.4 Supply Concerns The operational command is also concerned with R&M parameters that affect supply support. The frequency of demands on the supply system and the cost of that support are two areas of special interest. Although supply R&M parameters are normally used to assess support cost of a specified design, they can also be used to state operational constraints. Mission deployment requirements may limit the demands that can be placed on supply. Budget limitations may require the supply support costs to be within a programmed amount (e.g., Supply support contract dollars are limited).

4.4.1 Mean Time Between Demand (MTBD) Regardless of the impact on mission effectiveness, every demand on supply affects supply support cost. The cost of this support must be programmed, planned and budgeted. The average frequency of demands and the average cost of each demand are used to assist in determining the amount to be funded. The measure of the reliability related to the frequency of demands placed on supply is Mean Time Between Demand (MTBD). The definition of MTBD is: A measure of the system reliability parameter related to supply support. The total number of system life units divided by the total number of items demanded from supply during a stated period of time. The formula for MTBD is:

$$MTBD = \frac{\text{TOTAL LIFE UNITS}}{\text{\# OF ITEMS DEMANDED}}$$

4.4.2 Mean Parts Cost/Demand (MPC/D) Once the frequency of demands and the average cost of each demand is known, supply support costs can be estimated. The term associated with the cost of demands is Mean Parts Cost/Demand (MPC/D). The definition of MPC/D is: A measure of system support costs related to supply reliability. The total cost of parts demanded from supply divided by the number of demands during a stated period of time. The formula is:

$$MPC/D = \frac{\text{TOTAL PARTS COSTS}}{\text{\# OF DEMANDS}}$$

# APPENDIX B

## SYSTEM OPERATIONAL REQUIREMENTS DOCUMENT CHECKLIST

## SORD CHECKLIST

1. Does the SORD address, as a minimum, these Reliability and Maintainability factors:

   a. What is the required system R&M effectiveness?

   b. Based on system's employment and deployment concepts what is the system's required availability?

   c. What is the required dependability once a mission is initiated?

   d. What is required mission reliability for a mission of a stated duration?

   e. What is the maximum acceptable system restoral time?

   f. What frequency of critical software failures is acceptable?

   g. What frequency of hardware failures is acceptable?

   h. What maintenance and operations manpower constraints will the system be required to be operated in.

2. Do the above parameters reflect improved R&M system performance parameters over the system(s) being replaced?

3. Concerning maintenance, does the SORD address:

   a. Levels of maintenance?

   b. Skill level of blue-suit, robotic or contractor personnel designated to maintain the system?

4. Does the SORD specify quantitative values for operational and logistics support performance parameters?

5. Do quantitative and qualitative readiness requirements reflect the command R&M goals?

6. Are the R&M terms integrated such that:

   a. R&M parameters are explained in terms of how they affect operational capability?

   b. R&M terms used in the SORD are defined sufficiently for conversion into contractual terms in a future System Specification?

c. R&M goals and requirements are reasonable and compatible?

7. Are values for built-in test equipment (BITE) effectiveness defined?

8. Is the level of diagnostics defined?

9. Has software R&M been addressed?

# APPENDIX C

# R&M DATA ITEM DESCRIPTION LIST

## RELIABILITY DATA ITEM DESCRIPTIONS (DID)

The following is a list of data item descriptions associated with the reliability tasks specified in MIL-STD-785B.

| TASK | APPLICABLE DID | DATA REQUIREMENT |
|---|---|---|
| 101 | DI-R-7079 | Reliability Program Plan |
| 103 | DI-R-7080 | Reliability Status Report |
| 104 | DI-RELI-80255 | Report, Failure Summary and Analysis |
| 201 | DI-R-7081 | Reliability Mathematical Models |
| 202 | DI-R-2114 | Report, Reliability Allocation |
| 203 | DI-R-7082 | Reliability Predictions Report |
| 204 | DI-R-7085A | Report, Failure Modes, Effects and Criticality Analysis Report (FMECA) |
| | DI-R-7086 | FMECA Plan |
| 205 | DI-R-7083 | Sneak Circuit Analysis Report |
| 206 | DI-R-7084 | Electronic Parts/Circuits Tolerance Analysis Report |
| 208 | DI-R-30511 | Plan, Critical Item Control |

The following tasks have DIDs associated with them related to imposition of MIL-STD-781C:

| | | |
|---|---|---|
| 301 | DI-R-7040 | Report, Burn-in Test |
| 302, 303, 304 | DI-RELI-80250 | Plan, Reliability Test |
| 303, 304 | DI-RELI-80251 | Procedures, Reliability Test and Demonstration |

| | | |
|---|---|---|
| 303, 304 | DI-RELI-80252 | Reports, Reliability Test and Demonstration (Final report) |

Notes: (1) Only data items specified in the CDRL are deliverable. Therefore, those data requirements identified in the Reliability Program Plan must also appear in the CDRL.

(2) The PA should review all DIDs and assure, through tailoring, that the preparation instructions in the DID are compatible with task requirements as specified in the SOW.

## MAINTAINABILITY DATA ITEM DESCRIPTIONS (DID)

The following is a list of data item descriptions associated with the maintainability tasks specified in MIL-STD-470A.

| | | |
|---|---|---|
| 101 | DI-R-7103 | Maintainability Program Plan |
| 103 | DI-R-7104 | Maintainability Status Report |
| 104 | DI-R-7105 | Data Collection, Analysis and Corrective Action System, Reports |
| 201 | DI-R-7106 | Maintainability Modeling Report |
| 202 | DI-R-7107 | Maintainability Allocations Report |
| 203 | DI-R-7108 | Maintainability Predictions Report |
| 204 | DI-R-7085A | Failure Mode, Effects and Criticality Analysis (FMECA) Report |
| 205 | DI-R-7109 | Maintainability Analysis Report |
| 206 | DI-R-7110 | Maintainability Design Criteria Plan |
| 207 | DI-R 7111 | Inputs to the Detailed Maintenance Plan and Logistics Support Analysis |
| 301 | DI-R-7112 | Maintainability Demonstration Test Plan |

| | | |
|---|---|---|
| 301 | DI-R-2129 | Plan, Maintainability Demonstration (DI-R-2129 is to be used only when MIL-STD-471 is designated as the basis for MIL-STD-470A, Task 301) |
| 301 | DI-R-7113 | Report, Maintainability Demonstration (to be used only when MIL-STD-471 and its associated DI-R-2130A are not designated as a basis for MIL-STD-470A, Task 301) |

Notes: (1) Only data items specified in the CDRL are deliverable. Therefore, those data requirements identified in the Reliability Program Plan must also appear in the CDRL.

(2) The PA should review all DIDs and assure, through tailoring, that the preparation instructions in the DID are compatible with task requirements as specified in the SOW.

The following Data Item Descriptions are listed for reference purposes only. They have not been linked to any specific task number in any MIL-STD.

| Data Item | Description |
|---|---|
| DI-RELI-80247 | Thermal Survey Report |
| DI-RELI-80248 | Vibration Survey Report |
| DI-RELI-80249 | Environmental Stress Screening Report |
| DI-RELI 80253 | Failed Item Analysis Report |
| DI-RELI-80254 | Corrective Action Plan |
| DI-RELI-80261 | Production Inspection Equipment Test Systems Engineering Design Data |
| DI-RELI-80322 | Quality Conformance Inspection & Test Procedures |
| DI-RELI-80323 | Certification Demonstration Procedures |
| DI-RELI-80373 | Equipment Inspection/Testing Report |
| DI-RELI-80374 | Failure ANalysis Summary List |
| DI-3549A | Repair Level Analysis Report (RLA) |
| DI-7094 | Reliability Block Diagrams and Math Models Report |
| DI-R-3541/R-109-2 | Computer-Programmed Math Model for Reliability |
| DI-R-3547/R-115-2 | R&M Report on Commercial Equipment |